

Applied
Weather
Associates

August 19, 1997

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Dear Bob,

Enclosed is my peer review of the NOAA site-specific PMP study for the Cherry Creek drainage. I have incorporated modifications based on our phone call yesterday. I can be reached at North American Weather Consultants 801/972-3500 Wednesday through Friday of this week.

Keep me informed on the progress of the communications with the Corp and let me know of further requirements from my end. We should have some results from the mesoscale modeling by the end of next week.

Sincerely,


Edward M. Tomlinson, PhD

Atch:

Cpy: Dr Jarrett, USGS

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**Peer Review of the NOAA PMP study for the
Cherry Creek drainage in Colorado**

**Edward M. Tomlinson, PhD
Applied Weather Associates**

Overview

Applied Weather Associates (AWA) has conducted a peer review of the approach taken and techniques used by NOAA PMP study, "Site-Specific PMP for the Cherry Creek Drainage in Colorado". The following issues were identified:

1. Use of a procedure developed for the eastern US where there are no significant orographic features without additional study justifying its use at the foothills of the Rocky Mountains
2. Use of the 100-year precipitation climatology for spatial variations of rainfall without establishing that the 100-year precipitation climatology was based on rainfall events (vs snowfall, a significant consideration in Colorado)
3. Use of the assumption that extreme rainfall events over the Cherry Creek drainage is not significantly influenced by orography but increasing the PMP amounts by up to 14% due to orography
4. Use of orographic among-storm factors to adjust non-orographic within-storm factors (a technical issue which could significantly increase the rainfall volume)
5. The NOAA PMP amounts exceed the "maximized" largest storm which has occurred over or near the Cherry Creek drainage by over 60%.
6. The NOAA PMP maximum point rainfall values exceed the 100-year return period precipitation in the Cherry Creek drainage by roughly a factor of seven. Other PMP studies in the western have factors ranging from 1.4 to 7.5, which places the results of this study in the extreme upper range of those found in the other studies.

The approach used by NOAA has, in general, lead to larger PMP values for the Cherry Creek drainage than would have resulted from a more detailed study. The issues identified reflect on the reliability of the approach, assumptions and climatologies used as compared to the reliability that could be obtained from a more detailed study. Considering the importance of the results of a site-specific PMP study for the Cherry Creek drainage, the benefit in investing the time and effort required to enhance the reliability of the study appears to be justified.

Discussion

The US Army Corp of Engineers is considering modifications of the Cherry Creek Dam to provide safe passage of the Probable Maximum Flood (PMF). The rainfall associated with the computation of the PMF is provided by the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) in a report titled "Site-Specific PMP for The Cherry Creek Drainage in Colorado", dated July 12, 1995.

Applied Weather Associates (AWA) has been asked to review the site-specific study and provide comments on the approach taken and the applicability of the techniques used. The comments provided are general in nature since the specific details of some of the techniques, working papers and charts, and specific calculations of PMP values are not provided in the report.

The reviewer's overall impressions of the site-specific PMP study are concerns with the "site-specific" aspects of the approach used, and physical continuity and meaningfulness of the combination of assumptions and techniques used. Some of these concerns may be answered by knowing explicitly how the techniques used were applied and what climatologies were used and how. For example, the 100-year non-orographic precipitation is used but is not a published standard NOAA climatology product.

Approaches, techniques, and use of various climatologies in the site-specific study are discussed in this review. These discussions are meant to identify portions of the study where there are concerns related to the approach taken and techniques used. These concerns focus on the appropriateness of the approach from an atmospheric physics perspective and continuity of assumptions within the study.

AWA sent a letter to the Corp of Engineers, dated May 16, 1997, identifying issues related with the data associated with and the analysis of the May 30-31, 1935, storm which occurred over the Cherry Creek drainage as well as over other locations along and east of the Palmer Divide. After reviewing the NOAA site-specific PMP study, these comments, although still appropriate for the 1935 storm analysis, are not directly relevant to the NOAA study since data and analyses of the 1935 storm were not used directly in the study. The comments do apply indirectly since among-storm PMP values used in the NOAA study do incorporate PMP values from HMR 55A which are derived in part from the 1935 storm.

The following comments apply to the NOAA Site-Specific PMP study for the Cherry Creek Drainage in Colorado, dated July 12, 1995:

The study uses concepts developed in HMR 52, "Application of Probable Maximum Precipitation Estimates-United States East of the 105th Meridian" (Hansen et al., 1982). NOAA justified using the HMR 52 concepts west of its previous western limit (the 105th meridian) by referencing Section 1.8 of HMR 55A (Hansen, et al, 1988). That section states that HMR 52 should be applied to PMP estimates between the 103rd meridian and the orographic separation line (OSL). However, it is also stated that incomplete consideration was given to storms within this region to permit use of HMR 52 procedures without additional study. The OSL is defined in Section 3.2.1 of HMR 55A as being roughly 20 miles east of the base of the first upslopes of the Rocky Mountains as shown in Plate Vb from HMR 55A. As stated in the NOAA study, "Virtually all of the Cherry Creek Drainage lies west of this line...". The NOAA study also states that "It was decided to overlook this limitation in this study...". The orographic influence of the Palmer Divide on several historic storms was evaluated. In discussing the 1935 storm, HMR 55A, Section 2.4.1.5 states that "The Kiowa center occurred in an orographic region known as the Palmer Ridge....This suggest that ...the Kiowa center may have been initiated and enhance by orography...." In the discussion of the 1965 storm, Section 2.4.1.7 of the same report states that there were "deep layers of conditionally unstable air that required only minimal lifting to release the instability. This initial lifting was readily available in Colorado as a result of diurnal heating and both terrain and frontal lifting." In summary,

- 1) HMR 52 was not originally intended to be applied west of the 105th meridian,
- 2) HMR 55A states that HMR 52 could be applied as far west as the OSL but only after additional study,
- 3) the definition of the OSL in HMR 55A places most of the Cherry Creek drainage west of the OSL but the NOAA study overlooked this placement, and
- 4) analyses of historic extreme rainstorms over the Palmer Divide have identified orography as a significant factor.

The NOAA study justifies its use of HMR 52 for the Cherry Creek drainage by using non-orographic PMP depths provided in HMR 55A (Figure 8.7) along with depth-duration ratio maps (Section 10.3) which extend into the region just east of the OSL and depth-area-duration relations for non-orographic regions (Section 11.3.3). Further discussion should be provided for this westward extrapolation of non-orographic relationships as suggested by the additional study recommendation as stated in HMR 55A cited above.

After deciding to overlook the placement of most of the Cherry Creek drainage within the orographic region in HMR 55A, the NOAA study devises techniques to define the interaction of the within-storm non-orographic depths with orography. This technique uses the PMP maps and the non-orographic index map from HMR 55A to obtain among-storm orographic factors (K-factors). The use of K-factors is presented and discussed in NOAA Technical Memoranda NWS

HYDRO 39 and 41. These are site-specific PMP studies for drainages in Massachusetts/Vermont and Kentucky. The primary concern with this approach is the use of orographic factors to provide within-storm relationships for a non-orographic design storm using HMR 52 concepts. The NOAA study states that this is justified since the orographic factors range from 1.06 to 1.14 (i.e. increases in the non-orographic PMP depths of 6% to 14%). These values are in the lower range of those found in regions classified as orographic in HMR 55A. Additional concern arises from the use of among-storm orographic factors to modify the within-storm, non-orographic values to produce within-storm values of total PMP. Although the report does not provide the details of explicitly how this is accomplished, it appears that after extensive discussions on the importance of using within-storm relations for the design storm, among-storm values are in reality used.

The NOAA study states that all other values needed for the application of HMR 52 are available for the Cherry Creek Drainage. The study states that "...all storms explicitly or implicitly transposable to the Cherry Creek Drainage contribute depth-area-duration values in the HMR 52 techniques.". It appears possible that large mesoscale convective complex storms which occurred over the mid-west and provided some of the largest rainfall depths in HMR 51, could directly influence the depth-area-duration values used for the Cherry Creek drainage. From the information given, it cannot be explicitly determined if this occurred but since storms implicitly transposable to Cherry Creek contribute to the depth-area-duration values, it appears possible. For example, the September 17-19, 1926, storm at Boyden, Iowa, was transpositioned westward to the 101st meridian. However it appears possible that the depth-area-duration curves associated with that storm could have directly influenced the design storm for the Cherry Creek drainage. Since the storm was not transpositionable west of the 101st meridian, it should have no direct influence on a design storm over the 105th meridian. It is not clear whether this storm or other storms over the eastern US used in the production of HMR 51 provided non-representative rainfall depths for the Cherry Creek drainage.

The use of the GRASS software for computing rainfall depths over the watershed appears reasonable. Although there is some inconsistencies concerning the grid size used, even the most coarse of the grid sizes is appropriate.

There are several concerns related to the 100-year return level of precipitation. The first relates to the reliability of the analysis used. The NOAA precipitation map used was published in 1973 which suggest that the latest data used was probably about 1970. Considering that the Cherry Creek drainage has a low density of rainfall observations together with a relatively short period of record in 1970, the analysis should be updated using the additional 25+ years of data currently available (Telecom, Nolan Doesken, Colorado Climate Center, Aug 15, 1997). Additionally, the 1973 analysis did not separate precipitation by phase, i.e. snow vs

rainfall. Hence, for locations such as the Palmer Divide, the 100-year precipitation amount and geographic pattern could have been produced by rainfall observations, snowfall observations, or a combination of rainfall at some station and snowfall at an adjacent station. The important point here is if the 100-year precipitation pattern on the north slope of the Palmer Divide is derived from extreme snowfall events, it is inappropriate for use in evaluating extreme rainfall patterns. If the PMP storm for the Cherry Creek drainage is associated with generally southeasterly wind flows containing high levels of moisture from the Gulf of Mexico (as has been associated with historic large rainfall events along the Palmer Ridge), then orographic enhancement suggested by the 100-year precipitation pattern may not be appropriate. Hence it is important to compare the type of PMP storm and its associated inflow winds with the type of 100-year storm and its associated inflow winds. Mr Doesken will attempt to determine from the records at the Colorado Climate Center what precipitation records contributed to the establishment of the 100-year precipitation pattern for the north slope of the Palmer Divide (Telecom, Aug 15, 1997). The NOAA study used the level of the 100-year non-orographic precipitation in its calculations. This is not a published climatology. What appears to have been used were values perceived to be non-orographic from locations east of Cherry Creek. These perceived values need to be fully justified as being appropriate for use over the Cherry Creek drainage since they were derived from a geographically dissimilar region.

The PMP values derived from the NOAA study were compared with the 1935 storm. While the maximum point value "observed" exceeded the maximum point value from the study, the study PMP value for the area of the Cherry Creek drainage exceeded the 1935 storm by about a factor of 2. The conclusion stated in the study is that it is reasonable to believe that the 1935 storm maximized near 10 sq mi or less. Since there is a significant difference in the within-storm relationships between the design PMP storm and the 1935 storm, was the 1935 storm atypical for the Cherry Creek drainage location or were the within-storm relations used for the PMP design storm derived from storms which are not appropriate for use over the Cherry Creek drainage location? If the observed rainfall analysis of this storm is "maximized" using standard procedures and the maximization factor of 1.22 presented in HMR 51, the rainfall volume of the NOAA design storm exceeds the maximized 1935 storm rainfall volume by over 60%.

The NOAA study states that "The maximum point values at 6- and 24-hours from this study exceed the largest 100-year return period precipitation in the Cherry Creek Drainage by roughly seven times.". For comparison, data provided in Section 5.5 of HMR 49 indicate that the PMP values provided in that study for the Colorado River and Great Basin Drainages range from 1.4 to 5.9 times the 100-year point rainfall values. Table 13.1 from HMR 57 for the Pacific northwest states present maximum values that range from 3.2 to 7.5 times the 100-year precipitation values. The ratio

of PMP to 100-year values for the site-specific Cherry Creek drainage PMP study is decidedly in the extreme upper range of those found in other PMP studies for the western US.

In order to provide an estimation of the role of the orography associated with the Palmer Divide on the initiation and location of extreme storm events, AWA is working with Dr Jan Paegle with the Meteorology Department at the University of Utah. Case studies are being run using a numerical mesoscale meteorological model to estimate the influence of the terrain upslope and downslope of the Palmer Divide on the initiation of storm activity and the location of the resulting rainfall with respect to the ridgeline. Although the detail involved with these case studies cannot quantify rainfall amounts and exact locations, they should provide some quantification of the orographic influence of the Palmer Divide on extreme rainfall events.

Conclusions

These comments are provided to express concerns over various approaches, assumptions and climatologies used in the site-specific PMP study provided by NOAA for the Cherry Creek drainage. The approach used by NOAA has, in general, lead to larger PMP values for the Cherry Creek drainage than would have resulted from a more detailed study. The issues identified reflect on the reliability of the approach, assumptions and climatologies used as compared to the reliability that could be obtained from a more detailed study. Considering the importance of the results of a site-specific PMP study for the Cherry Creek drainage, the benefit in investing the time and effort required to enhance the reliability of the study appears to be justified.